Background Paper #2

Interchange Access Management

prepared for

Oregon Department of Transportation
Salem, OR 97310

by

Robert D. Layton
Oregon State University
Department of Civil, Construction, and Environmental Engineering
Corvallis, OR 97331

August 1996

Background

This paper draws on a draft Interchange Management Policy that was prepared in 1989 by Oregon Department of Transportation. The primary focus of this paper is interchange management within the context of access management. It does not deal with all the interchange funding, approval, design and construction issues necessary for planning and design of future interchanges.

Purpose

The purpose of this paper is to provide direction for the planning, design and access management of interchanges, particularly where they connect to the crossroads. The guidelines and standards established will be employed in the review, evaluation and design of new interchanges, modifications to existing interchanges and cross road operation, design and access control.

Definitions

The following definitions are used in this policy:

Crossroad - the lower functional classification facility of the two facilities an interchange connects.

Expressway - a divided major roadway for through traffic with partial control of access and generally with interchanges at major crossroads.

Freeway - an expressway with full control of access. Full control of access means that the authority to control access is exercised to give preference to through traffic by providing access connections with selected public roads only and by prohibiting crossings at grade or direct private driveway connections.

Interchange - a system on interconnecting roadways in conjunction with one or more grade separations that provides for the movement of traffic between two or more roadways or highways on different levels.

Interchange management area - the area defined by a distance along the mainline and crossroads in all directions extending beyond the end of the interchange ramp terminal intersections or ramp or speed change lane tapers.

For crossroads it is the crossroad on both sides of the interchange to the nearest intersection with a public street. The distance on either side should not be less than 1,320 ft. and generally not more than 2,640 ft.

For non-freeway mainlines in either direction it is the shortest distance to: the nearest interchange; 1320 ft. from the beginning or end of speed change lanes; or the nearest public road intersection. For freeway mainlines, it is the distance to the ramp or speed change lane tapers of the next interchange in either direction.

Mainline - the higher functional classification facility of the two facilities the interchange connects.

Management Strategies

Interchange plans are part of the long-term transportation system planning effort and must have effective strategies for 20-30 years in the future. They also need to consider potential need for transit, and park and ride facilities. Management strategies can use transportation system operations/control, land use, and circulation elements to achieve the intent of the interchange operation priorities. These include:

A. **Traffic Controls**. Traffic controls that may be considered as part of management strategies include: signal phasing, intersection channelization, turn restrictions, traffic queue detection, traffic signal interconnection, and ramp metering.

1. Traffic signals on the cross street should be interconnected and operated to assign vehicle right of way with priority placed on moving traffic off the main highway or freeway and away from the interchange area, consistent with safety considerations.
2. Improvements may be needed to supplement the physical capacity of conflicting, yet important traffic movements through the interchange on the local facility or from the local facility to the main highway. This may require the restriction of access to properties within the interchange area or the separation of local and interchange access traffic through the construction of circulation/distribution systems discussed below.
3. Ramp metering may be necessary to ensure efficient operation on the main highway by reducing merge conflicts, eliminating the platooning effect created by ramp terminal signalization, and reducing short distance travel on the freeway where the available capacity is limited. Operations and access on the crossroad may be affected by queue spill-back from the ramp metering location.

B. **Access Control**. Access to the cross street must be controlled a sufficient distance on either side of the ramp connections to reduce conflicts and protect the ramp operations. Control may include spacing of public and private access points to the crossroad facility, and the use of a physical median barrier. Distances are provided in Attachments A and B.

The distance to the first signalized intersection should be at least 1320 ft. (1/4 mi.) beyond a ramp intersection or a free flow ramp terminal, as shown in Attachments A and B.

C. **Circulation/Distribution System**. Development of a system of streets around the interchange shall be encouraged to circulate and distribute traffic to land uses in the area with a minimal impact on the mainline and crossroad. This system should be designed to direct traffic returning to the interchange to a signalized or full intersection at least 1320 ft. (1/4 mi.) from the ramp intersections.

D. **Land Use Controls**. The comprehensive plan and zoning designations should acknowledge the function and role of the interchange and the spacing standards. Future right of way needs should also be included in the comprehensive plan.

E. **Protective Buying and Sale of Excess Property**.

1. Strategies should be developed to insure property necessary for future expansion of the interchange is available and at the least relative cost. The strategies must be compatible with pertinent federal and state requirements.
2. When feasible, protective buying should be done if it is deemed more cost effective than alternatives or found to be more cost effective than buying the property in the future.

F. **Grade Separated Crossings**. Grade separated crossings, without ramps, may be used to:

1. Keep low volume intersecting roadways open for effective service.
2. Avoid having interchanges too close to each other.
3. Connect to existing or planned local connectors.
4. Provide crossing corridors that relieve traffic demand on crossings at interchanges.

G. **Balanced Interchange Design with Ultimate Mainline Facility**. The interchange design must be consistent with the plan for the mainline as expressed in the corridor plan, taking account of:

1. Level of service (LOS) operating standards in the LOI policy.
2. The selection of mainline and other interchanges that would be affected by the interchange over the planning period.
3. Future improvements in corridor plan: number of travel lanes, auxiliary lanes, high occupancy vehicles (HOV) lanes, exclusive transitways, modifications to existing interchanges, and planned new interchanges.
4. Projected LOS considering planned facilities, projected mainline traffic volumes, traffic generated by build-out of the interchange vicinity, anticipated changes in local travel resulting from the installation of a new interchange.
5. Planned surface street improvements that would relieve the freeway.

The interchange shall not be constructed or improved unless necessary supporting improvements identified in the corridor plan are in place or firmly committed to construction when needed.

H. Relieve Off-Ramps

1. Design, operation and management of the interchange shall give primary emphasis to off-ramp movements so traffic does not back up onto the freeway.
2. Consideration must be made for handling special events which may exceed what otherwise may be suitable design hour conditions, i.e., fairs and sporting events. Location and design of access facilities to special event land uses must take account of the potential queuing, increased delays and safety impacts, and may require larger than typical spacing standards.

I. Frontage Road Relocation/Closure

1. Frontage roads which are closer than the spacing standards for access to cross streets shall be either relocated or closed. Where feasible, local streets should be planned and built to provide for adequate access to adjacent property without interfering with the operation off the interchange ramps.

J. Closure of Interchange or Ramps

1. Certain ramps of the existing interchange or the entire interchange may be removed when the existing interchange is substandard or where better interchange facilities are already or can be developed in the area. To serve the area formerly served by the interchange, connecting roads will be provided to adjacent interchange facilities.

K. Local Street System

1. Interchanges shall connect to an adequate arterial street system with the necessary frontage roads, cross streets, channelization, access control, etc. In most cases the cross road should be a major or minor arterial. The connecting road design shall meet all applicable design standards.
2. The cross streets at interchanges should meet the following requirements:
   a. The cross street must have sufficient capacity in either direction for a distance of 2,640 ft. (1/2 mi.) from the end of the interchange ramp or speed change lane tapers at level of service “C” in rural areas and “D” in urban areas. This is to assure the cross street is able to carry all the traffic that the interchange will present to it and insure adequate traffic movement away from the interchange facility.

b. The cross streets shall serve a reasonably large area, not just the area immediately around the interchange. The cross streets shall serve at least a minor arterial function in the area street system.

c. Except as provided below, no public or private access shall be allowed on the cross street for a distance of at least 660 ft. from a ramp intersection or ramp or speed change lane taper. Where distances are less than 660 ft., access points shall generally be confined to right turns in/out. This may require construction of a physical median barrier.

Multilane Cross Road Criteria

A. Spacing Between Ramp Terminal and Nearest Major Intersection

There are a number of factors and considerations that dictate the spacing to the nearest major intersection. These include the needed distance to accommodate the weaving maneuvers from free flow off-ramp onto the cross road facility to the left turn bay at the intersection. The weaving maneuvers must be completed by the time the end of the queue at the intersection is reached. Therefore, the spacing to the nearest major intersection is the weaving distance plus the queue length at the intersection. This distance is shown as distance Y on the left side of Attachment A. Figure 1 shows the results of analysis that evaluated the weaving distance and the queue length for urban, suburban and rural conditions. The conditions assumed for the analysis are shown below. The volumes are assumed to be typical of the area and volume labels.

Table 1. Typical Operating Conditions Assumed for Analysis

Area	Speed	Cycle	Yellow	# of Phases	Cross Road Volume, $\left(\frac{veh}{hr}/lane\right)$			Off-Ramp Volume (vph)
					High	Moderate	Low	
Urban	35 mph	120^s	3^s	4	1000	800	600	600
Suburban	45 mph	90^s	4^s	3	500	400	300	300
Rural	55 mph	60^s	5^s	2	300	200	100	100

The analysis of the weaving distance is based on the Weaving Method by Leisch, given in Figure 1. Table 2 summarizes the analysis of weaving distance. An assumption is made that 50% of the left turns at major the intersection is contributed by off-ramp traffic. The results are not very sensitive to this assumption because the weaving traffic includes all the cross road volume.

Table 2. Weaving Distances for Four Lane Cross Road with 10 and 20% Left Turns

Area	Volume Level	Cross Road Volume, vph/lane	Off Ramp Volume, vph	Weaving Volumes		Weaving Distance	
				10% LT	20% LT	10% LT	20% LT
Urban (35 mph)	High	800	600	1710	1820	900	920
	Moderate	700	500	1495	1590	790	830
	Low	600	400	1280	1360	660	710
Suburban (45 mph)	High	500	400	1070	1140	1300	1380
	Moderate	400	300	855	910	1030	1100
	Low	300	200	640	680	750	820
Rural (55 mph)	High	300	150	637	675	2100	2200
	Moderate	200	100	425	450	1350	1500
	Low	100	50	212	225	600	650

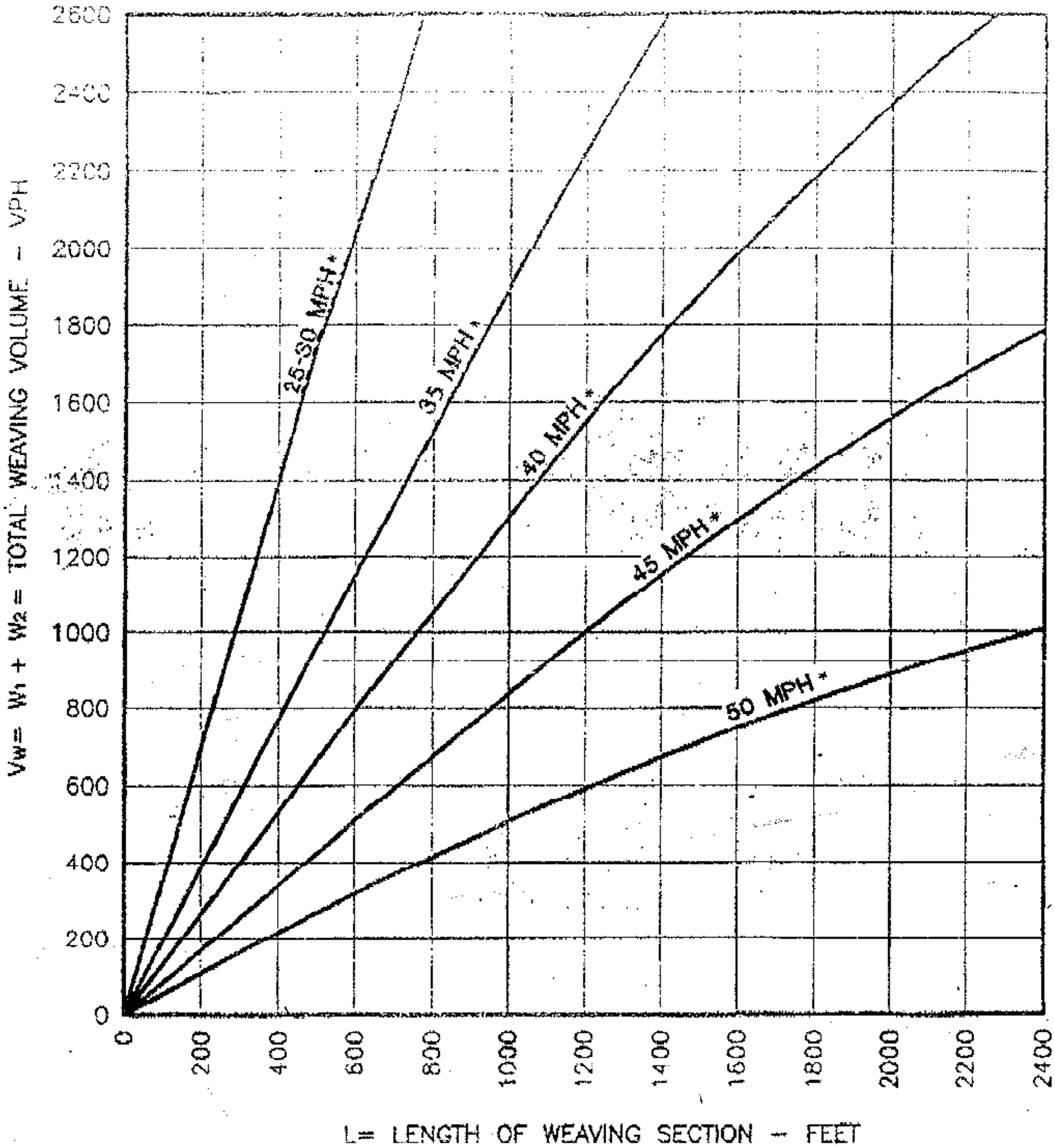


Figure 1. Analysis of Service Road Weaving Conditions
adapted from "Procedure for Analysis and Design of Weaving Sections,"
FHWA Project DTFH51-82-C-00050 by Jack E. Leisch, 1982.

The queuing distance must also be taken into account to assure that vehicles have adequate distance to weave comfortably to the left before being trapped in the right lane by vehicles queuing back from the intersection. Otherwise, forced lane changes to avoid the queuing vehicles can result in both operations and safety problems.

This queuing distance can be determined using the deterministic queuing analysis approach by:

$$Q = pqt$$

where q = flow rate in vehicles/sec.

t = period of queuing, sec.

p = randomness factor

The randomness factor recognizes the peaking or randomness of vehicles arriving at a location. A factor of 1.5 is sometimes used with high volumes as might be seen on a major arterial, with a factor of 2 used at locations where a higher degree of randomness is expected. Oregon Department of Transportation has adopted a randomness factor of 2.

The time period, t, refers to the amount of time that the vehicles are arriving at the intersection, and are not being served, i.e., not receiving a green phase. For purposes of this analysis an unblocked condition is assumed for the phasing strategy, that is, the vehicles for the through phase can arrive and be served on a green phase. Therefore, the time period is the cycle length minus the green time:

$$t = cy - G$$

where t = time period for queuing per cycle

cy = cycle length, sec.

G = green time, sec.

It is also possible to estimate the amount of queuing based on the Poissin distribution, which is a statistical mathematical distribution used to describe the occurrence of rare,

$$\Pr(n, q/t) = \frac{e^{-qt(qt)^n}}{n!}$$

random events.

where Pr (n,q/t) = probability of n vehicles arriving in time period, t, with volume of q

q = flow rate, veh/sec

t = time period, sec

n = number of vehicles in time period

This analysis is represented by Figure 2.

A comparison of the queue sizes determined for high volume shows that the use of the deterministic queuing method with a randomness factor can give very erroneous results. The randomness factor only gives acceptable results for very low volumes, as seen in Tables 3 and 4.

The queuing conditions estimated from the Poisson distribution yields the most realistic results. In fact, the deterministic method with the randomness factor is attempting to approximate the results of the probabilistic based analysis using the Poisson distribution. Consequently, the queue sizes based on the Poisson distribution are used here.

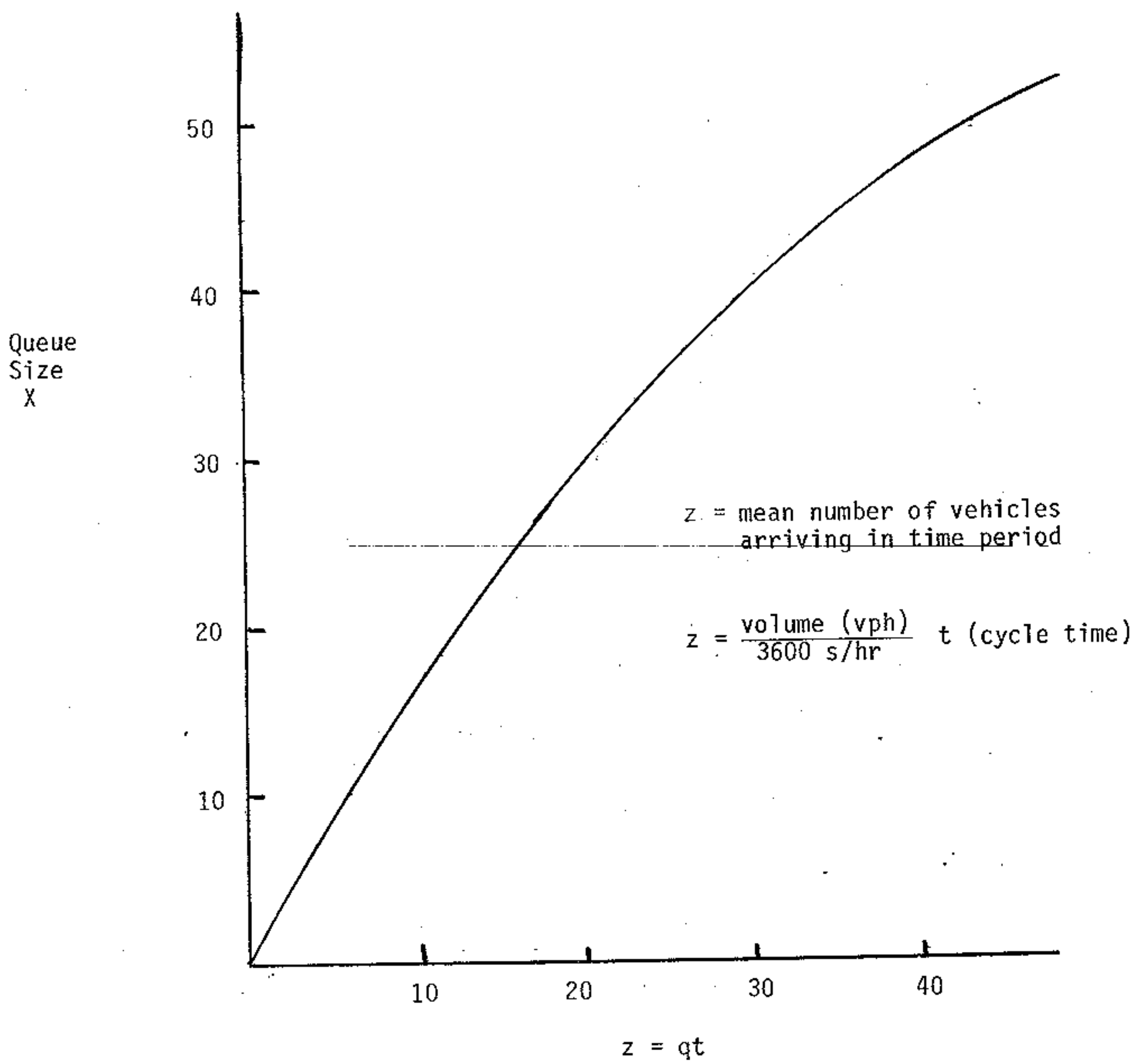


Figure 2. Queue Size Based on 95% Confidence Level Cumulative Poisson Probabilities

Table 3. Queue Sizes for Urban, Suburban and Rural Conditions by Deterministic Queuing and Probabilistic Poisson Analysis with 10% Left Turns

Area Type	Through Volume (2 lanes) vph	Typical Ramp (2 lanes) vph	Total Queuin g Volume vph	Cycle sec	Throug h Green sec	Left Turn Green sec	Yellow sec	Phases >	t sec	Queue Size, veh			Queue Length ft
										1.5 qt	2.0 qt	Poisson	
Urban (35 mph)	1600	600	1980	120	60	13	3	4	60	25	33	25	625
	1400	500	1710	120	52	12	3	4	68	24	32	24	600
	1200	400	1440	120	44	11	3	4	76	23	31	23	575
Suburban (45 mph)	1000	400	1330	90	42	10	4	3	48	14	18	15	375
	800	300	1045	90	42	10	4	3	48	11	14	12	300
	600	200	760	90	42	10	4	3	48	8	10	9	225
Rural (55 mph)	600	150	713	60	25	▪	5	2	35	5	7	7	175
	400	100	475	60	25	▪	5	2	35	4	5	5	125
	200	50	238	60	25	▪	5	2	35	2	3	3	75

Table 4. Queue Sizes for Urban, Suburban and Rural Conditions by Deterministic Queuing and Probabilistic Poisson Analysis with 20% Left Turns

Area Type	Through Volume (2 lanes) vph	Typical Ramp (2 lanes) vph	Total Queuin g Volume vph	Cycle sec	Throug h Green sec	Left Turn Green sec	Yellow sec	Phases >	t sec	Queue Size, veh			Queue Length ft
										1.5 qt	2.0 qt	Poisson	
Urban (35 mph)	1600	600	1760	120	54	19	3	4	66	24	32	24	600
	1400	500	1520	120	46	18	3	4	74	24	32	24	600

	1200	400	1280	120	39	14	3	4	81	22	29	23	575
Suburban (45 mph)	1000	400	1260	90	35	17	4	3	55	15	20	16	400
	800	300	990	90	35	17	4	3	55	12	15	13	325
	600	200	720	90	35	17	4	3	55	9	11	10	250
Rural (55 mph)	600	150	676	60	25	▪	5	2	35	5	7	6	150
	400	100	450	60	25	▪	5	2	35	4	5	5	125
	200	50	225	60	25	▪	5	2	35	2	3	3	75

The distances for weaving and queuing are combined to give the required spacings to the next major intersection from a free flow off ramp terminal. These values are given in Table 5 and are then shown graphically in Figure 3.

Table 5. Queue Sizes for Urban, Suburban and Rural Conditions by Deterministic Queuing and Probabilistic Poisson Analysis with 10% Left Turns

Area Type	Volume Level	Weaving Distance		Queuing Distance		Spacing	
		10% LT	20% LT	10% LT	20% LT	10%	20%
Urban (35 mph)	High	900	970	625	600	1525	1570
	Moderate	790	830	600	600	1390	1430
	Low	660	710	575	575	1235	1285
Suburban (45 mph)	High	1300	1380	375	400	1675	1780
	Moderate	1030	1100	300	325	1330	1425
	Low	750	820	225	250	975	1045
Rural (55 mph)	High	2100	2200	175	150	2275	2350
	Moderate	1350	1500	125	125	1475	1625
	Low	600	650	75	75	675	725

The analyses were performed for both 10% and 20% left turn at the major intersection, and were not found to change the results significantly. A summary of the analysis is presented in Figure 1. As can be seen from that figure, a spacing of 1320 ft., or 1/4 mi., is a minimum spacing for moderate volumes for urban, suburban and rural conditions and speeds. However, this only provides for low volume conditions, a spacing of 1/2 mi. would accommodate all conditions, or 2,000 ft. would handle all but high volume urban conditions.

The situation with a signalized intersection, as the off ramp terminal, also yields a minimum spacing to the major nearest intersection of 1320 ft. This is the minimum spacing that can be used, and still provide coordinated progression between the intersections. This is described in the discussion paper on Access Management Classification and Standards.

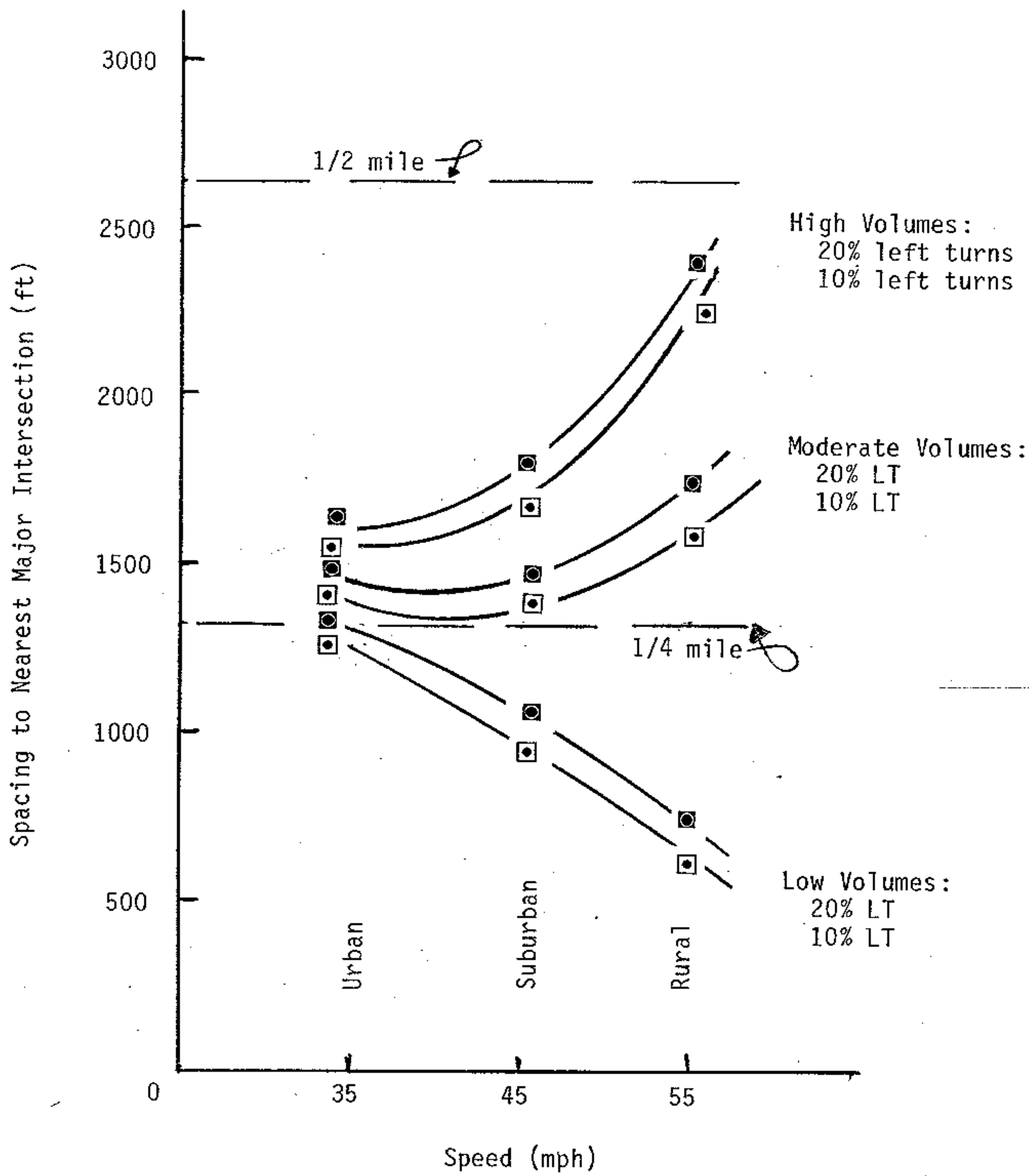


Figure 3. Spacing to Nearest Major Intersection from a Free Flow Off Ramp Terminal

B. Spacing to First Drive/Access from Off Ramp

1. *First Drive / Access on the Right from Off Ramp*. This is the distance from the ramp terminal to the first drive/access approach. This is shown as the distance "X" on Attachments A and B. The spacing to the first drive/access approach could be based on a number of operations or safety criteria. The three most logical criteria are presented in the following.

   a. Stopping Sight Distance. The stopping sight distance to the first or second access or drive may be used to determine the spacing to the first drive/access from the off ramp. Figure 4 demonstrates the logic behind the use of the stopping sight distance for the right turn conflict. With the single right turn conflict it is assumed that the driver must have enough distance once entering the roadway to see operations and vehicles at the next drive with enough distance to stop. The double right turn conflict assumes drivers are keeping track of conditions at two drives. With the driver arriving on the cross road from the off ramp or passing the ramp terminal, only the single right turn conflict criteria, or desirable stopping sight distance to the first drive is logical. This is based on the desirable stopping sight distance from the 1990 AASHTO Greenbook.

Table 6. Desirable Stopping Sight Distances

Area	Speed, mph	Sight Distance, ft
Urban	35	250
Suburban	45	400
Rural	55	550

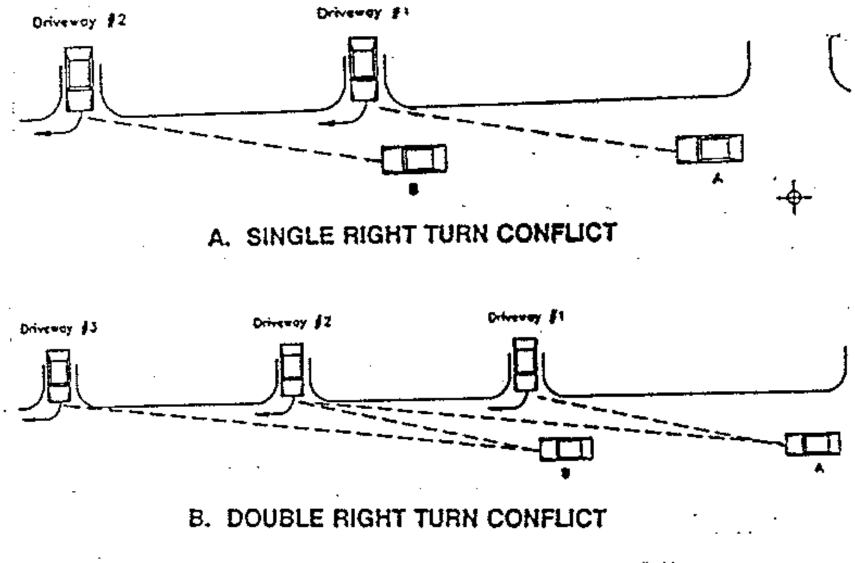


Figure 4. Schematic Illustration of the Right Turn Conflict Overlap

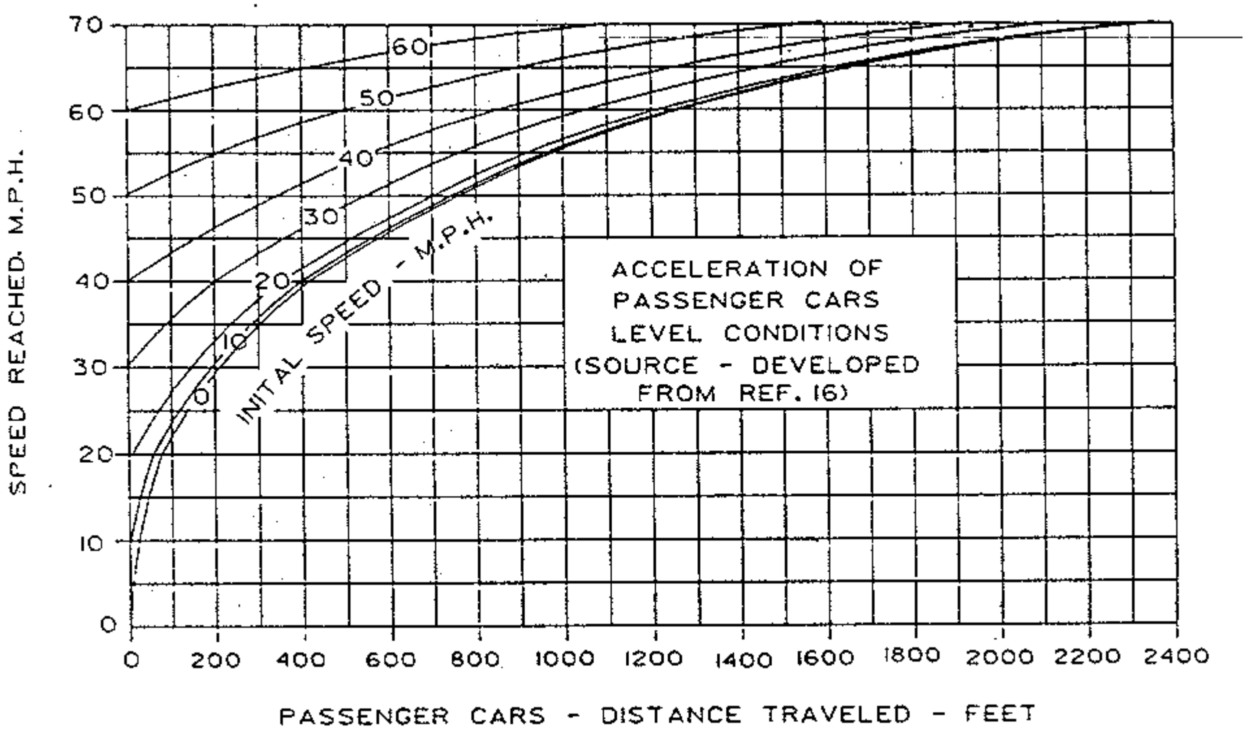


Figure 5. Acceleration of Passenger Cars on Level Terrain

b. Minimum Access Spacing to Maximum Egress Capacity. This criteria uses 1.5 times the distance to accelerate from 0 to through traffic speed, based on the acceleration data from the 1990 AASHTO Greenbook, p. 749, shown in Figure 5. This criteria is based on research performed by Major and Buckley[1] which reported that driveways spaced at distances greater than 1.5 times the distance required to accelerate from zero to the speed of through traffic will reduce delay to vehicles entering the traffic stream and will improve the traffic absorption characteristics of the traffic stream. Spacings based on acceleration distances for passenger cars on level grades are given in Table 7.

Table 7. Minimum Access Spacing to Provide Maximum Egress Capacity

Area	Speed	1x Acceleration Distance	1.5x Acceleration
Urban	35 mph	300 ft.	450 ft.
Suburban	45 mph	575 ft.	860 ft.
Rural	55 mph	1000 ft.	1500 ft.

c. Decision Sight Distance Criteria. This criteria is based on the 1990 AASHTO Greenbook on decision sight distance. This provides the driver with adequate sight distance to perceive and react to unexpected, unusual, and/or complex conditions. The decision sight distance varies with the area character and the type of maneuver required to negotiate the location properly. The maneuvers include (1) stopping on rural or urban roads and, (2) a speed, path, and/or direction change on urban, suburban or rural roads.

[1] I.T. Major and D.J. Buckley, "Entry to a Traffic Stream, Proceedings of the Australian Road Research Board, 1962.

Table 8. Decision Sight Distance Criteria

Area	Speed	Stop	Speed/Path/Direction –
Urban	35 mph	620 ft.	710 ft.
Suburban	45 mph	640ft.	810 ft.
Rural	55 mph	590 ft.	870 ft.

Based on 1990 AASHTO Policy on Geometric Design

The operations on cross roads in the vicinity of on-ramps and off ramps are complex and often unlike the operation throughout the rest of the road/street system. Driver's are exiting or entering a facility that is higher speed, access controlled and often divided. The entrances and exits are presented in many different configurations, therefore drivers must discern the appropriate entries or exits from other drives and approach facilities. This requires greater perception-reaction time to sort out the more complex situation. Further, driver's expectations on freeways and expressways are quite different than on surface streets and two lane roadways. The driver anticipates fewer distractions and access points along these roadways.

The spacing to the first drive or access road must take account of decision sight distance. A spacing of 660 ft. provides a distance slightly greater than the decision sight distance for stopping on both rural and urban roads. Decision sight distance provides an increase in perception-reaction time as the situation complexity increases, therefore, the perception-reaction time is longer for urban areas with the increased complexity of traffic operations and land use.

The braking distance is greater on higher speed rural facilities than urban. Consequently, the decision sight distances for stopping for both rural and urban facilities sums to about 660 ft. Also, this is half of 1320 ft. (1/4 mi.) which places the drive/access approach halfway between the ramp terminal and the nearest signalized intersection, or major intersection.

2. *First Median Opening from Off Ramp Terminal - Access to First Drive on Left.* The location of first median opening, or access to a left drive/access, from a free flow off ramp requires adequate distance for weaving maneuvers to be made. Based on typical volume conditions and vehicles emitting the intersection area for the various areas, the weaving distances are shown in Table 9, based on Figure 1.

Table 9. Minimum Weaving Distance to First Median Opening and First Drive/Access on Left

Area Type	Volume Level	Through Volume (2 lanes), vph	Typical Ramp Volume, vph	Total Weaving Volume, vph	Weaving Distance, ft
Urban (35 mph)	High	2000	800	2001	1050
	Moderate	1600	600	1601	830
	Low	1200	400	1201	620
Suburban (45 mph)	High	1000	400	1001	1200
	Moderate	800	300	801	950
	Low	600	200	601	700
Rural (55 mph)	High	600	150	601	2220
	Moderate	400	100	401	1250
	Low	200	50	201	520

The slowing of vehicles as they enter the turn bay or median opening impaction operations and safety. However, some of this effect is taken into account in the weaving operations. Desirably, the median opening will serve well as an area develops, perhaps from rural to suburban, and ultimately, urban. A distance of 1200 - 1250 could serve typical rural and suburban locations, up to high volume conditions. This is roughly 1/4 mile, which fits well with other requirements of both intersection and median spacings.

3. *Spacing Between Nearest Access/Drive and the On-ramp Terminal.* The primary concern in determining the location of the last access/drive before an on-ramp is the necessary decision sight distance for a speed, path or direction change in a complex situation. Since the access/drive interrupts the drivers attention, the drive should be placed at least a distance equal to the decision sight for the type of area upstream of the taper to the on-ramp. These are shown in Table 10.

Table 10. Decision Sight Distance for Speed/Path or Direction Changes

Area	Typical Speed	Decision Sight Distance
Urban	35 mph	710 ft.
Suburban	45 mph	810 ft.
Rural	55 mph	870 ft.

A secondary effect is the weaving between vehicles entering from the drive /access and the vehicles destined for the on-ramp. The effect is difficult to analyze because both typical on-ramp volumes and volumes from the drive/access must be known. The higher these volumes, the greater effect of the weaving operations. The vehicles in the left lane can be assumed not be involved in the weave unless they are on-ramp vehicles. Using the typical volume conditions, the required weaving distances can be estimated as shown in Table 11. For purposes of this analysis, assume 50 vehicles/hr from the access.

Table 11. Required Weaving Distances between an On-ramp and the Nearest Access/Drive

Area Type	Through Volume vphpl	Typical Ramp Volume, vph	Access Volume, vph	Total Weaving Volume, vph	Weaving Distance, ft
Urban (35 mph)	1000	800	50	1850	975
	800	600	50	1450	750
	600	400	50	1050	550
Suburban (45 mph)	500	400	50	950	1150
	400	300	50	750	900
	300	200	50	550	650
Rural (55 mph)	300	150	50	500	1700
	200	100	50	350	1000
	100	50	50	200	500

Based on these decision sight distances for speed, path or direction change, Table 10, and the weaving distances, Table 11, it can be seen that any access closer than 1000 ft. can potentially disrupt operations and safety with even a low entering volume from the access. These controls of decision sight distance and weaving distance both must be provided, but are not additive.

Two Lane Cross Road Criteria

C. Spacing to Nearest Major Intersection with Two Lane Cross Road. Driver expectancy is a major concern with two lane cross roads because the drivers present have varying levels of expectations. The drivers exiting from the freeway/expressway have higher levels of expectations based on the higher levels of speeds, design, operations, and access control they have been experiencing. The drivers on the two lane cross road naturally have lesser expectations. The mix of drivers, complexity of the interchange area and uniqueness of the operations, ramp layouts and design elements requires more time for drivers to perceive and react properly. Consequently, decision sight distance must be provided and is a major factor in assuring smooth operations and safety.

A second major factor is the queuing distance required to accommodate all of the vehicles waiting to enter the nearest intersection. With a two lane facility near an intersection this must be accommodated in one lane for all vehicles entering the intersection from the interchange, unless a wider section of roadway with a left turn lane is provided at the intersection. Obviously, weaving is not an issue.

The stopping sight distance to the back of queue must use the decision sight distance for a stop condition rather than stopping sight distance because the conditions are complex, unexpected and somewhat unique. The operations around interchange ramps may be different than those experienced on typical roads and streets. The decision sight distance for a stop condition is given in Table 12.

Table 12. Decision Sight Distance for the Stop Condition

Area	Speed	Decision Sight Distance
Urban	35 mph	620 ft.
Suburban	45 mph	640 ft.
Rural	55 mph	590 ft.

Based on 1990 AASHTO Policy on Geometric Design

The analysis of queuing conditions for two lane cross roads uses the same assumptions for volume and operating conditions assumed as typical previously for multilane highways. The results of the queuing analysis are summarized in Table 13.

Table 13. Queue Size for Two Lane Road for Urban, Suburban and Rural Conditions by Deterministic Queuing and Probabilistic Poisson Analysis

Area Type	Through Level	Through Volume vph	Typical Ramp Volume vph	Total Queuing Volume ⚐ vph	Cycle sec	Through Green sec	Yellow sec	Phases >	t sec	Queue Size, veh			Queue Length ft
										1.5 qt	2.0 qt	Poisson	
Urban (35 mph)	High	800	600	1050	120	65	3	3	55	24	32	24	600
	Moderate	700	500	900	120	56	3	3	64	24	32	24	600
	Low	600	400	750	120	47	3	3	73	23	31	23	575
Suburban (45 mph)	High	500	400	675	90	35	4	3	55	16	21	17	425
	Moderate	400	300	525	90	35	4	3	55	12	16	13	325
	Low	300	200	375	90	35	4	3	55	9	12	10	250
Rural (55 mph)	High	300	150	337	60	25	5	2	35	5	7	6	150
	Moderate	200	100	225	60	25	5	2	35	4	5	5	125
	Low	100	50	113	60	25	5	2	35	2	3	3	75

⚐ Assumes 25% left turns which are accommodated by a separate left turn bay. This result is insensitive to the % of left turns assumed. For example, if 35% left turns is assumed, a queue size from the Poisson distribution of 24 vehicles also results for the high volume level with urban conditions.

In summary, the spacing to the next major intersection is determined from the sum of the decision sight distance to stop and the queuing distance, based on the Poisson distribution. These results are shown in Table 14 and Figure 6.

Table 14. Spacing to Nearest Major Intersection from Free Flow Off Ramps for Two Lane Cross Roads

Area Type	Volume Level	Decision Sight Distance to Stop ft	Queuing Distance (Poisson based) ft	Spacing ft
Urban (35 mph)	High	620	600	1220
	Moderate	620	600	1220
	Low	620	575	1195
Suburban (45 mph)	High	640	425	1065
	Moderate	640	325	965
	Low	640	250	890
Rural (55 mph)	High	590	150	740
	Moderate	590	125	715
	Low	590	75	665

D. Spacing to First Drive on Right from Free Flow Off Ramp. The conditions are very similar to those experienced on a multilaned cross road for the first drive on the right. Consequently, the same criteria should be applied as for multilaned cross roads.

E. Spacing to First Drive on Left from Free Flow Off Ramp. The conditions for this spacing are the same as for the first drive on the right. The driver must have adequate time/distance to discern the vehicle is stopping, or is stopped to turn left. This should also provide the decision sight distance for the stopping condition.

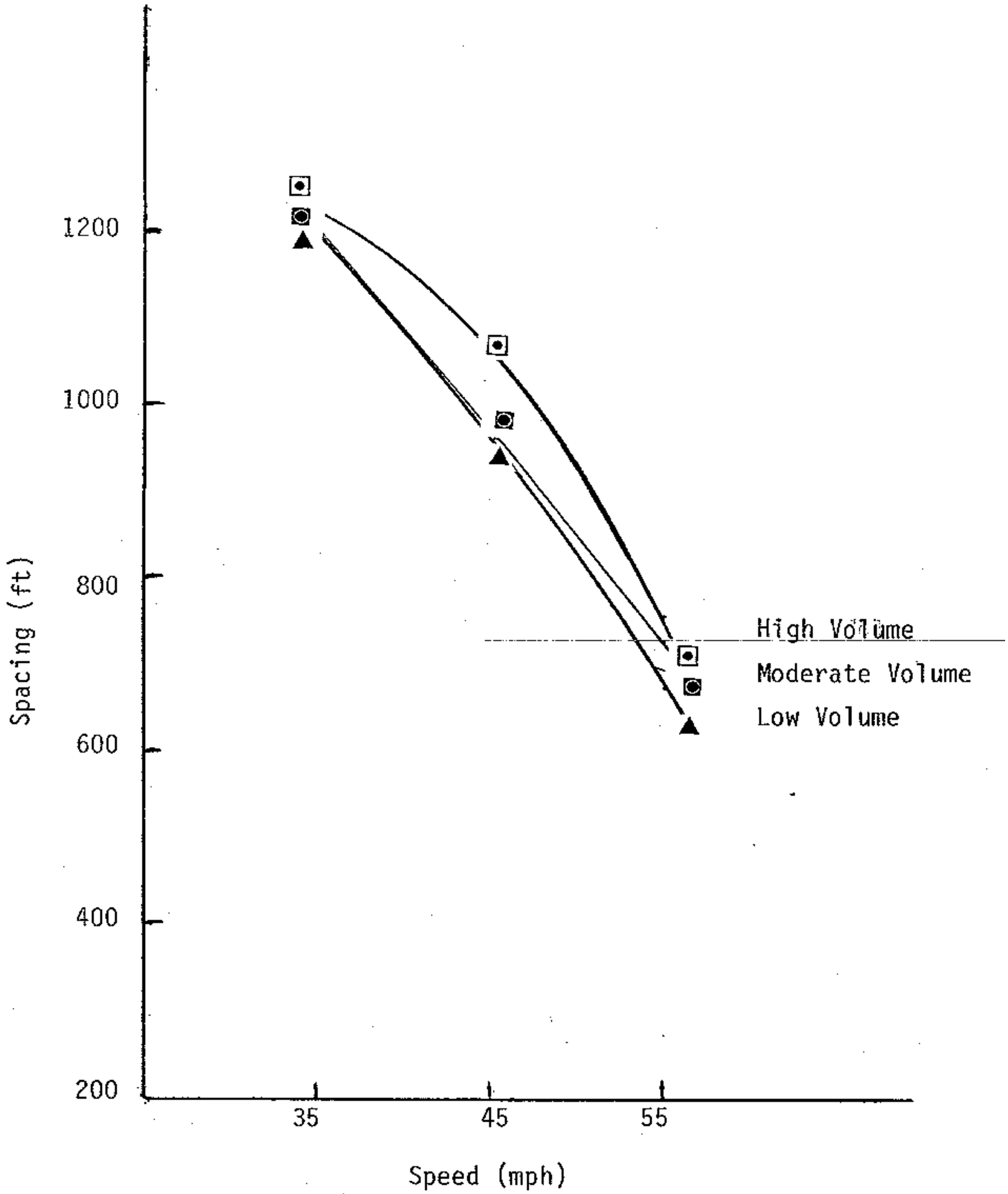


Figure 6. Spacing to Nearest Major Intersection from Free Flow Off Ramps for Two Lane Crossroads

Table 15. Decision Sight Distances for the Stop Condition

Area	Speed	Decision Sight Distance	
		to Stop	to Change Speed/Path/Direction
Urban	35 mph	620 ft.	710 ft.
Suburban	45 mph	640 ft.	810 ft.
Rural	55 mph	590 ft.	870 ft.

However, this drive is also the drive/access upstream of the on-ramp for which the decision sight distance for a speed, path, or direction change must be made. These criteria require longer spacings, and thus will control.

Attachment A

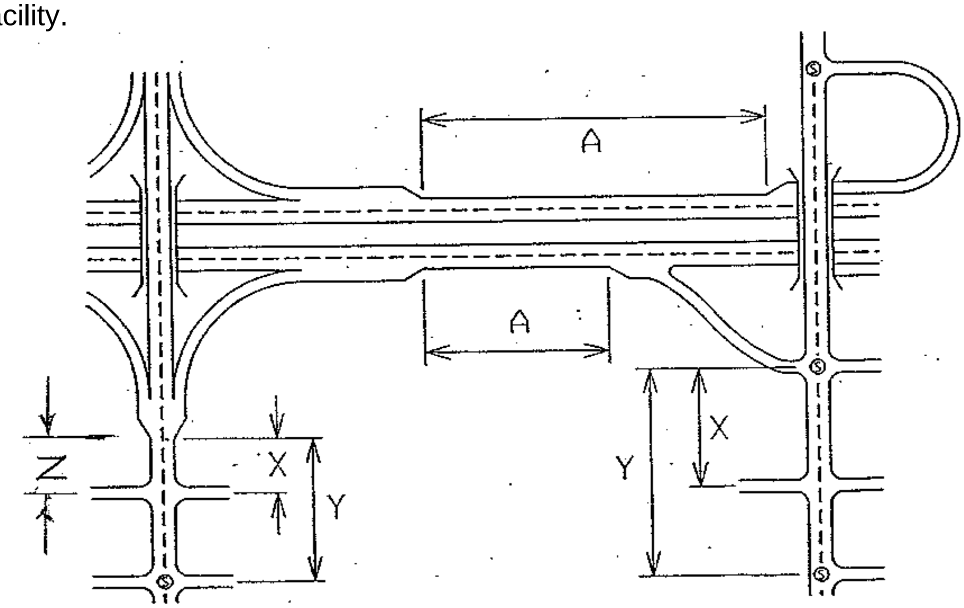
Minimum Spacing Standards Applicable to Freeway Interchanges with Two Lane Cross Roads

Category	Area Type	Spacing Dimension			
		A	X	Y	Z
Freeway	Urban	1 mi.	660 ft.	1320 ft.	660 ft.
	Suburban	1 mi.	990 ft.	1320 ft.	990 ft.
	Rural	2 mi.	1320 ft.	990 ft.	990 ft.

Minimum Spacing Standards Applicable to Freeway Interchanges with Four Lane Cross Roads

Category	Area Type	Spacing Dimension			
		A	X	Y	Z
Freeway	Urban	1 mi.	660 ft.	2640 ft.	1320 ft.
	Suburban	1 mi.	990 ft.	2640 ft.	1320 ft.
	Rural	2 mi.	1320 ft.	1320 ft.	1320 ft.

Notes: If cross street is a state highway, these distances may be superseded by Access Management Policy depending on LOS and assigned access category for cross street facility.



Attachment B

Minimum Spacing Standards Applicable to Non-Freeway Interchanges

Category of Mainline	Area Type	Free Flow Speed of Mainline	Spacing Dimension						
			A	B	C	D	O	X	Y
Expressway	Urban	45	1 mi.	1/2 mi.	1/2 mi.	1/2 mi.	~◉	660'	1320'
	Rural	55	2 mi.	1/2 mi.	1 mi.	1 mi.	~◉	660'	1320'

~◉ Determined by Access Management Policy

Notes: If cross street is a state highway, these distances may be superseded by Access Management Policy depending on LOS and assigned access category for cross street facility.